Post-doc position:

Innovative wave front sensing for future Extreme AO systems on the VLT and ELT

Application to the RISTRETTO project

Place: Laboratoire d'Astrophysique de Marseille, France and Geneva Observatory, Switzerland
Duration: 18 months, with possible 18 months extension
Funding: WOLF project grant (PI: T. Fusco), ONERA and Geneva Observatory (PI: C. Lovis)
Starting date: as soon as possible!
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Context

Europe is currently building the world's largest telescope to answer fundamental questions of contemporary astrophysics: the 39-m Extremely Large Telescope (ELT), which will see first light by the end of 2026 at Cerro Armazones (Chile). However, ground-based telescopes suffer from a significant loss of angular resolution caused by the atmospheric optical turbulence. Adaptive Optics (AO) is a technology based on a deformable mirror that corrects in real time the incoming distorted wave front. The key element of an AO system is the **wave front sensor** (WFS) that measures the incoming turbulent phase. This element drives the final performance of the AO and therefore of the astrophysical instrument it feeds.

The state-of-the-art extreme AO systems, used in the challenging context of exoplanet imaging, are controlling deformable mirrors with a high number of actuators (e.g. 41x41 over the 8-m diameter pupil of the telescope). The instruments VLT/SPHERE and GEMINI/GPI are both equipped with such extreme AO, using a Shack-Hartman WFS (SH-WFS). **One of the main limitations comes from the temporal bandwidth error (or servo-lag) that appears when atmospheric turbulence is evolving faster than the AO correction** (Fig. 1).

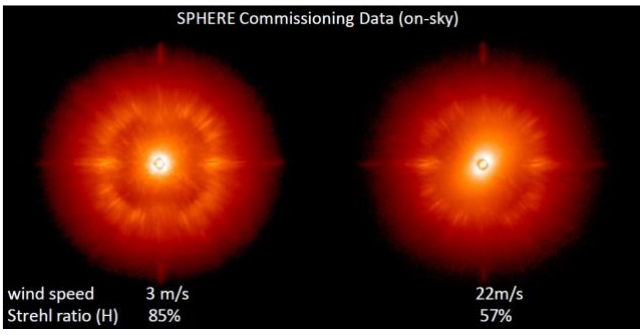

Figure1: *Impact of the AO temporal error on VLT/SPHERE coronagraphic images. Left: under slow evolving turbulence. Right: under fast evolving turbulence (contrast decreased by one magnitude).*

To tackle this issue, the AO correction must be applied at a faster rate, typically 2 to 3 times faster than the current 1 kHz standard used for both SPHERE and GPI. Using a SH-WFS would dramatically reduce the limiting magnitude, that is to say, the number of suitable targets. **Running faster AO correction requires a more sensitive and optimized wave front sensor.**

Optimizing a wave-front sensor means maximizing the Signal to Noise Ratio (SNR) of each phase measurements. This consists in (1) finding the most efficient transformation procedure of phase into intensity, (2) minimizing the number of pixels on which the signal is coded and (3) developing new signal processing approaches to deal with the various noises inherent to photon detection: photon noise, detector read-out and background. **In that context, several innovative sensors have been proposed in the past decade**. Recently, **LAM** and **ONERA** have proposed a unified and rigorous analytical description of a new class of WFS that includes the Pyramid WFS: the **Fourier Filtered WFS** (FF-WFS).

These innovative WFS are meant to be integrated into future cutting-edge instruments that aim at imaging and characterizing extrasolar planets from the ground. A particular focus will be put on the RISTRETTO project, led by the Geneva Observatory (Chazelas et al. 2020; Lovis et al. 2017), which will aim at the exoplanet reflected light through the combination of high contrast imaging in the visible and high resolution spectroscopy (see http://ristretto.astro.unige.ch). The idea is to build a visitor instrument for the VLT, using the AOF facility as a first stage AO system. The development of a dedicated 2nd stage AO system that will ensure an unprecedented correction, in the visible, of both turbulence and telescope induced perturbations is a key part of the RISTRETTO project. It will give the global framework and the long term vision to the post-doctoral contribution.

The postdoctoral researcher would contribute to the development of the AO part of the instrument by proposing, implementing and testing (on sky) new cutting-edge wavefront sensing approaches (combining multi-stage sensing and correction, data fusion and non-linear / AI-based solutions) allowing to reach the ambitious astrophysical goals of the RISTRETTO instrument.

Postdoctoral work

In this context, the objectives of the post-doctoral project are threefold:

1. Develop **versatile and multi-stage WFS schemes** that will ensure both ultimate performance and good robustness to variable observing conditions in the framework of exoplanet imaging with a primary application to the VLT/RISTRETTO project, and strong synergies with VLT/SPHERE+ and ELT/PCS;
2. Identify the key AO loop parameters to propose **innovative calibration procedures** to ensure the optimal on-sky performance under a wide range of observational and environmental conditions;
3. Lead the **final design and implementation** in-lab and on-sky of these new concepts with existing and/or in development facilities. In the laboratory, the researcher will work on the *LOOPS* bench at LAM to implement the proposed WFS schemes. For the on-sky validations, two AO benches (currently under development) could be considered: the *PAPYRUS* bench on the 1.52m telescope of the Observatoire de Haute Provence (France), and the KalAO facility on the Swiss 1.2m telescope at La Silla Observatory (Chile).

The postdoctoral researcher will be at the heart of the AO developments for the next generation of high contrast instrumentation for the VLT (e.g. RISTRETTO, SPHERE+, MAVIS) and the ELT (e.g. HARMONI, HIRES, PCS). The LAM, ONERA and Geneva Observatory *are leading various instrumental projects and the postdoctoral researcher will benefit from the teams' expertise (high-contrast imaging, adaptive optics, wave front sensing) and resources (simulation tools, optical benches and access to telescope facilities). In addition they are offering a dynamic international research*

environment with several teams working on astronomical applications using the innovative instrumental concepts developed by our teams.

The work will be conducted in collaborations with various actors of the AO community and within international consortia of large projects (e.g. RISTRETTO, SPHERE+, PCS). The postdoctoral researcher will lead her/his analysis within this project and her/his developed skills will have a strong impact on the growing adaptive optics community.

Applications

Junior and senior applications will be evaluated at the same level.
LAM, ONERA and the Geneva Observatory are actively committed to equal opportunity in employment.

Interested candidates should send by e-mail the following documents (in one .pdf file):
-A statement of research and experience (1-2 pages),
-A *Curriculum Vitae,*
-A list of publications.
Applications received before August 1st 2021 will be given full consideration.